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Graph-based Data Representation for Crash-worthiness Simulations

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We consider graph modeling for a knowledge graph for vehicle development, with a focus on crash safety. An organized schema that incorporates information from various structured and unstructured data sources is provided, which includes relevant concepts within the domain. In particular, we propose semantics for crash computer aided engineering (CAE) data, which enables searchability, filtering, recommendation, and prediction for crash CAE data during the development process. This graph modeling as an example for the overall CAE process considers the CAE data in the context of the R&D development process and vehicle safety. Consequently, we connect CAE data to the protocols that are used to assess vehicle safety performances. The R&D process includes CAD engineering and safety attributes, with a focus on multidisciplinary problem-solving. We describe previous efforts in graph modeling in comparison to our proposal, discuss its strengths and limitations, and identify areas for future work.

Today, the Finite Element method (FEM) is the preponderant tool for automotive crash simulation [1]. The large amount of complex data confronts engineers with the challenge to explore the simulation results sufficiently, due to lack of engineering time and limitations of data storage, processing and analysis tools. This need pushed the automotive companies to uptake preand post-processing tools to be more efficient in analysing the data, with the goal to spend the engineers time on solving the problem instead of data processing. Nevertheless, even with all achievements so far, data flow within the companies is still inefficient. Yet, crash scenarios studied in the development phase are just a tiny proportion of the real crashes. The need to increase the number of simulations and the limitation of CAE engineers'time emphasizes the importance of an intelligent system to capture domain knowledge as knowledge graphs (KGs) for automotive, which we call car-graph.

The modeling of CAE data is challenging since the data is complex, and several disciplines with different requirements interact with the CAE data. However, the flexibility of graph data modeling reflects existing uncertainties and allows the modeling to evolve. In this work, we present an initial attempt to define a semantic representation that stores information regarding the different crash scenarios, the vehicle design deviations during the development process, and the quantities of interest that measure the outcome. Consequently, we propose semantic selections that follow the development concepts, FE-modeling terminology, crashworthiness assessment quantities, and other relevant entities. Additionally, these can be used as input for machine learning (ML) analysis, where the graph modelling also allows storing ML results. Our vision is to use data modeling and ML to auto-assess the cause and effect in the development process to assist engineers and, in particular, to assess the safety of different, uncalculated crash scenarios.

As an example, we will present a summary of an industrial implementation for pedestrian analysis. Here, the number of simulations increases enormously for each design in pedestrian analysis. We will illustrate how CAE-web visualizes this big data and allows its intuitive and easy exploration. In this visualization, we present the traditional CAE reporting as a dynamic web interface and graph-ML technics on this data. We propose two groups of visualization: zoom-out and zoom-in views. Zoom-out views consider the assessment of many simulations, for example, development trees, status tables of safety performance, or embedded results from machine learning. However, zoom-in views contain single/multiple simulation assessments and comparisons.
Additionally, the user has a multi-view functionality to combine zoom-in and zoom-out views. In multi-view, zoom-out views are selection inputs for updating zoom-in views.

Keywords: crash-worthiness; CAE data management; CAE knowledge; Car knowledge graph; data representation

References

[1] P. Spethmann, C. Herstatt, and S. H. Thomke, "Crash simulation evolution and its impact on R&D in the automotive applications,"International Journal of Product Development, vol. 8, no. 3, pp. 291–305, 2009.

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